

WHAT IS CLAIMED IS:

1. A semiconductor device comprising:
a semiconductor substrate, and
a circuit element using an insulating film formed
5 on said semiconductor substrate,

said insulating film containing a silicon compound
containing at least one element selected from the group
consisting of an oxygen and a nitrogen, and a metal
compound containing a metal other than silicon and at
10 least one element selected from the group consisting of
an oxygen and a nitrogen, nano-crystals being formed in
said insulating film, the size of said nano-crystal
being small enough to permit observation of a
polycrystalline ring as a diffraction image when an
15 electron beam having a beam diameter of the nanometer
order is incident in parallel to said insulating film
surface.

2. The semiconductor device according to claim 1,
wherein said a silicon compound is a compound selected
20 from the group consisting of a silicon oxide, a silicon
nitride, and a silicon oxynitride.

3. The semiconductor device according to claim 1,
wherein said nano-crystal grains are made of said metal
compound.

4. The semiconductor device according to claim 2,
wherein said nano-crystal grains are made of an oxide,
25 a nitride or an oxynitride of a metal other than

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silicon.

5. The semiconductor device according to claim 1, wherein said nano-crystals grains has a diameter falling within a range of between 1 nm and 10 nm.

5. 6. The semiconductor device according to claim 1, wherein said insulating film has a thickness falling within a range of between 3 nm and 20 nm.

10 7. The semiconductor device according to claim 1, wherein an oxynitride film is formed between said semiconductor substrate and said insulating film.

8. The semiconductor device according to claim 1, wherein said metals other than silicon is at least one metal selected from the group consisting of Ti, Ta, Y, Al, Zr, La, Hf, Nb and elements of lanthanum series.

15 9. The semiconductor device according to claim 1, wherein said functional element is a MOSFET, and said insulating film is a gate insulating film of said MOSFET.

20 10. The semiconductor device according to claim 1, wherein said nano-crystals being formed in said insulating film, the size of the largest nano-crystal grain in said insulating film being not larger than the thickness of said insulating film.

25 11. The semiconductor device according to claim 10, wherein the size in the thickness direction of said insulating film of the largest nano-crystal grain formed in said insulating film is substantially

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equal to the ~~thickness~~ of said insulating film.

12. The semiconductor device according to claim 1,
wherein a part of the periphery of at least one of said
nano-crystals being positioned within a distance of
5 0.7 nm from the interface of said insulating film.

13. The semiconductor device according to claim 1,
wherein said insulating film is a mixed film containing
said silicon compound and said metal compound.

14. A method of manufacturing a semiconductor
10 device according to claim 1, comprising:

forming an insulating film containing a silicon
compound containing at least one element selected from
the group consisting of an oxygen and a nitrogen, and
a metal compound containing a metal other than silicon
15 and at least one element selected from the group
consisting of an oxygen and a nitrogen, on a
semiconductor substrate under temperatures at which
crystallization does not take place; and

applying a heat treatment to precipitate a nano-
20 crystalline metal oxide within said mixed film.

15. A method of manufacturing a semiconductor
device, comprising:

forming insulating film being a mixed film
including a silicon compound containing at least one
25 element selected from the group consisting of an oxygen
and a nitrogen, and a metal compound containing a metal
other than silicon and at least one element selected

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from the group consisting of an oxygen and a nitrogen on a semiconductor substrate under temperatures at which crystallization does not take place; and

5 applying a heat treatment to precipitate a nano-crystalline metal oxide within said mixed film.

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